NOTES ON BASE The base chart was prepared with advisory assistance rom Dr. Gerard P. Kuiper and his collaborators, D. W. G. Arthur and E. A. Whitaker. CONTROL

The position of features on this chart was determined

through the use of selenographic control established pri-

marily from the measures of J. Franz and S. A. Saunder

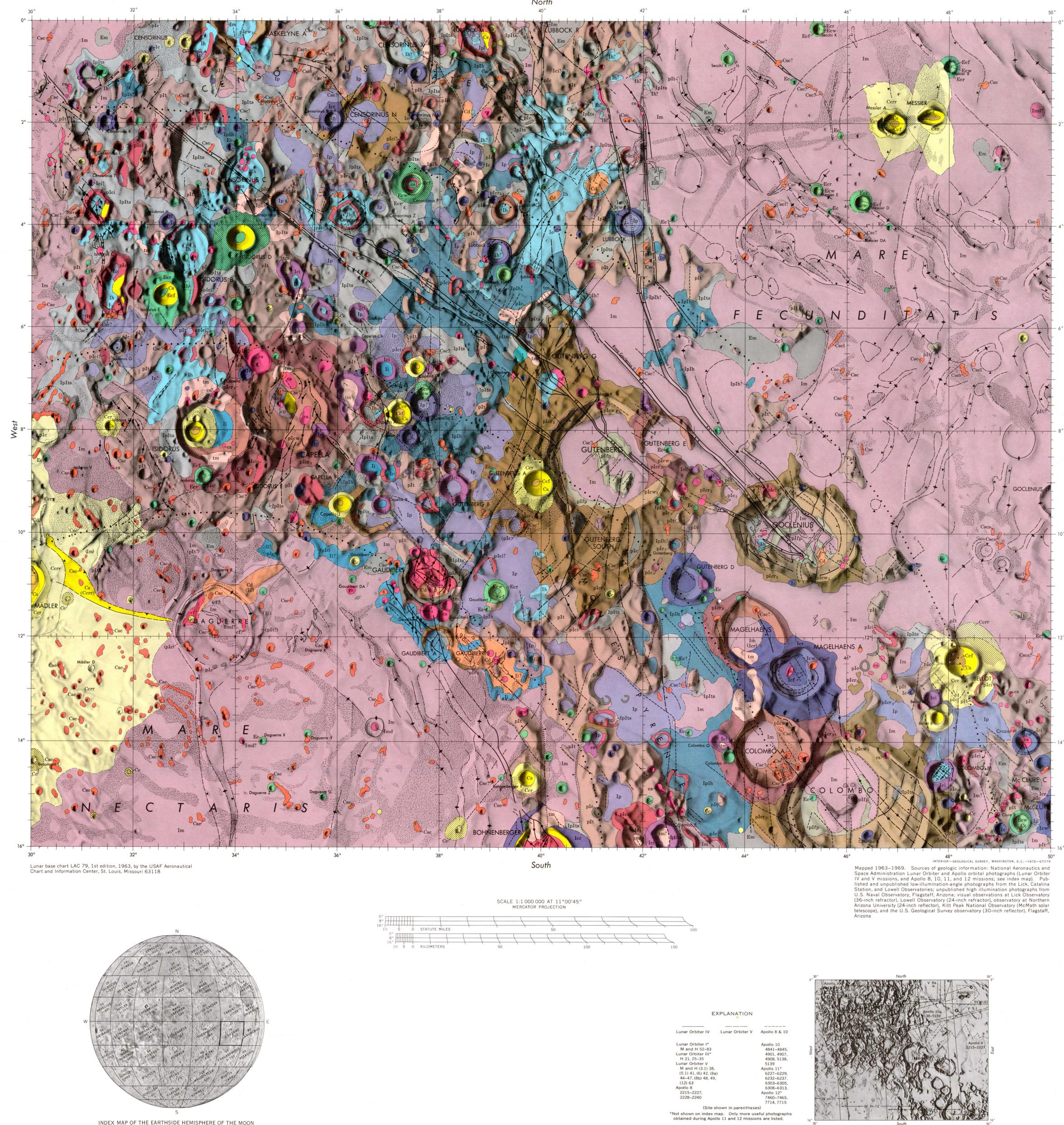
as compiled by D. W. G. Arthur and E. A. Whitaker in

the Orthographic Atlas of the Moon, Edited by Dr. Gerard The feature names were adopted from the 1935 International Astronomical Union nomenclature system with ninor changes introduced in the Photographic Lunar Atlas, Edited by Dr. Gerard P. Kuiper, 1960. Craters designated by capital letters were selected from the I.A.U. list of Named Lunar Formations. Supplementary lettered formations have been added in accordance

with the criterion suggested by Blagg and Müller. They

are designated by lower case letters.

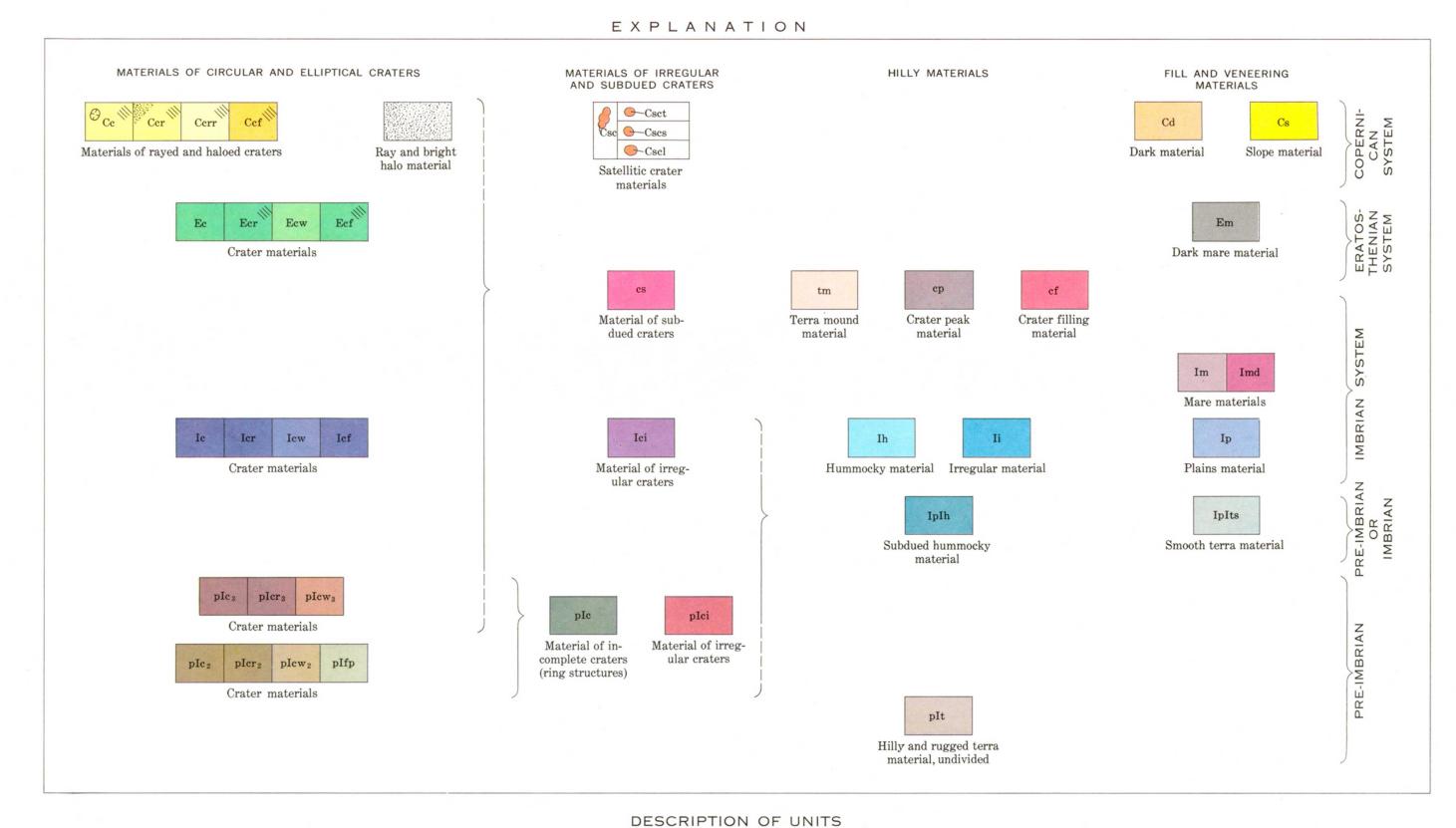
The configuration of the relief features shown on this chart was interpreted from photographs taken at Lick, Mc Donald, Mt. Wilson, Yerkes and Pic du Midi Observa tories, and published in the 1960 Edition of the USA Lunar Atlas and unpublished photographs from the Lunar and Planetary Laboratory, University of Arizona and Department of Astronomy, University of Manchester, Visual observations made with the 24 inch Lowell refracting telescope, Flagstaff, Arizona, have also been used to add and clarify details. The pictorial portrayal of relief forms was developed using an assumed light source from the West with the angle of illumination maintained equal to the angle of slope of the features portrayed. Cast shadows were eliminated to enable complete interpretation of relief forms.



GEOLOGIC MAP OF THE COLOMBO QUADRANGLE OF THE MOON

Number above quadrangle name refers to lunar base chart (LAC series);

number below refers to published geologic map



MATERIALS OF CIRCULAR AND ELLIPTICAL CRATERS Cc, Ccr, Ccr, Ccf, materials of rayed and haloed craters

c, rim and wall materials, undivided. Most craters small (<5 km), bright naloed, circular to nearly circular; appear fresh, have sharp, unmodified rim rests; generally surrounded by bright or very bright rays. Diagonal line pattern where dark to very dark; dark halos smooth and more extensive than bright halos; crater rims shown by hachured outlines. Interior mostly very oright; intermediate in dark-halo craters r, rim material, undivided. Surrounds crater rim crest: generally blocky to hummocky near rim crest; lower, smoother farther out; entirely smooth in small craters (<15 km) at Orbiter IV resolution. Diagonal line pattern

where darker than surroundings; stippled where brighter than surroundings. In larger craters grades out into: Ccrr, rim material, radial. Low ropy ridges subradial to crater. Most extensive around Theophilus (west of quadrangle); subdued but continuous positive topography; boundary placed where grades into flat mare surface. Around orth-south directions normal to long axes of craters. Diagonal line patter here darker than surroundings of, floor material. Level to irregular floors generally of intermediate and high albedo; smooth to rough and hilly; rough in Messier craters and possibly in Bellot. Diagonal line pattern where dark (Messier craters and Bellot)

Material of impact craters, except low-rimmed dark-halo crater on mare ridge west of Bohnenberger, believed volcanic. Ccr, bulk ejecta; emplaced prininally as flap of ejecta rotated outward and upward from crater and deposited in inverted stratigraphic position. Ccrr. probably deposited by outward movement and piling up of ejecta; where dark, possibly ejecta and fallback darkened by injection of dark bolide material. Dark ponds west of Messier craters may be fluidized ejecta. Ccf, slumped brecciated material from walls; fallback, possibly containing admixed bolide material; and impact-induced volcanic

Ray and bright halo material

Brighter than surrounding terrain; extends outward from rim deposits of Co pernican craters. Elongate, irregular plumose streaks and patches, commonly in partly interconnected loops and arcs; streaks approximately radial or tangential to primary crater; symmetrical to irregular bright halos around smal fresh craters. Superposed on all units except Cs and Cd. Distributions of conspicuous rays and satellitic craters coincide. Rays traceable to craters beyond quadrangle as follows: Theophilus, radiating from Theophilus rim material (unit Ccrr in Mare Nectaris) in west; Tycho, trending northeast near Bohnenberger; Stevinus-group craters, trending northwest in east half of quadrangle; Langrenus, trending east-northeast in Mare Fecunditatis; Taruntius, trending approximately south near Messier

Freshly exposed, brecciated, shock-whitened rock, deposited as continuous to iscontinuous veneers, as low ridges and trains of boulder-sized to fine-grained ragmental debris, and as mixtures of secondary and tertiary ejecta in and adjacent to satellitic craters. Source craters are those listed above. Doublet ray system of Messier A (Copernican) may be material derived from disrupted wall of older crater (Eratosthenian), breached and ejected as two separate flaps or trains of debris during impact formation of Messier A

Ec, Ecr, Ecw, Ecf, crater materials

Copographically similar to corresponding Copernican units or somewhat smoother; mostly darker, and no distinguishable bright halo or rays. Diagonal line pattern where darker than surroundings Ec, crater material, undivided. Topography more subdued, shallower than unit Cc. Albedo intermediate to high, commonly somewhat higher in uplands than maria. Queried where could be Copernican or Imbrian Ecr, rim material. Albedo near rim crests commonly high in uplands and inter mediate in maria; low around Messier B in mare; locally intermediate on outer rim of Censorinus F in upland cw, wall material. Steep smooth slopes. Albedo high in uplands, intermediate to high in maria; darker than unit Cs ef, floor material. Smooth to locally hummocky. Albedo intermediate

Same origin as for corresponding materials of Copernican craters. Bright nalos and ray materials probably once present around some craters but deaded by mixing and turnover by small impacts and radiation darkening Wall material, mass-wasted debris. Relatively higher albedo of wall and inner rim materials in uplands possibly due to greater pre-impact brecciation of upland source materials (Elston and Holt, 1967; Elston, 1968)

Ic, Icr, Icw, Icf, crater materials

pIc₃, pIcr₃, pIcw₃, crater materials

Topography more subdued than in Copernican and Eratosthenian craters ore small superposed craters. Rim crests largely complete, moderately subdued. Craters range from moderately deep to moderately shallow Ic, rim and wall material, undivided. Topography subdued. Includes small (≈ 5 km) floorless, shallow craters and larger (≈ 10 km) craters containing diverse floor materials Icr, rim material. Albedo intermediate. Comparatively smooth; appears faintly hummocky in high-resolution Apollo orbiter photographs Icw, wall material. Moderately steep, mostly smooth; terraced in Magelhaens A. Albedo high to intermediat

Icf, floor material. Small extent, mostly hilly (generally covered by other units

and not visible); largest exposures in Magelhaens A and Gutenberg D. Albedo mostly intermediate Mainly impact crater materials, as for corresponding materials of younger craters. Mostly modified by volcanic processes, as inferred from floor-filling materials. Larger craters resemble the smooth-rimmed crater Kopff in the

Orientale basin identified by McCauley (1968, p. 1995-1996) as a possible cal-

Moderately subdued, nearly circular to subpolygonal craters. Commonly overlapped by mare material and other younger materials, intersected by younger craters, and more subdued and modified than Imbrian craters. Rim crests subdued but mostly well defined, except where younger materials superposed. Small craters (<10 km across) nearly circular, although commonly ncomplete; surrounded by smooth rim material of local extent. Craters larger than 30 km polygonal, walls terraced, rims subdued but hummocky; degraded t otherwise similar to large, young rayed craters such as Copernicus and Theophilus (not in quadrangle). Crater Isidorus (pprox 25 km) nearly circular smooth-rimmed, smooth-walled; morphologically similar to, although more ubdued than, Imbrian craters of comparable size c3, rim and wall material, undivided. Albedo of most intermediate pIcr₃, rim material. Moderately rugged and hummocky near rim crest, grading to more subdued away from crest. Albedo of most intermediate. Around

pIcw₃, wall material. Steep, smooth to locally terraced. Albedo high complete craters may be calderas pIc₂, pIcr₂, pIcw₂, pIfp, crater materials

Isidorus, slightly darker and smoother in fine detail than elsewhere

Similar to materials of younger pre-Imbrian craters, some of which intersect and overlie them. Crater rim crests fairly sharp locally, but mostly broader, more subdued, and more modified by cratering than in younger craters. Small craters incomplete, highly subdued, and partly to largely masked by deposits of younger material. Goclenius elliptical; otherwise morphologically similar to other large pre-Imbrian craters

------Contact Dashed where approximately located or gradational; queried where uncertain or doubtful

Buried contact Inferred buried material shown by symbol in parentheses

downthrown side

LUNAR ORBITER AND APOLLO PHOTOGRAPHIC COVERAGE OF

COLOMBO QUADRANGLE

Inferred fault Solid line at base of sharp scarp; dashed at base of subdued scarp; dotted where concealed; queried where uncertain or doubtful. Bar and ball on apparent

Lineament Interpretation: Fault, but sense of movement undetermined

Mare ridge Line marks ridge crest. Triangular barbs point down Mainly linear; locally circular and subcirparently outlining crests of concealed craters

Interpretation: Places of upwelling of mare material

Mare scarp Dashed where approximately located. Line marks most abrupt change in slope, at top or base of scarp. Friangular barb points downslope. Delineates mesa plateaus, and broad swales in northeast part of quad Interpretation: Places of possible constructional volcanic activity, structures in underlying pre-mare rocks, or monocline-like structures

Narrow and gently sinuous to linear; associated lowof graben at 42°W., and 2° to 3° S. are chain craters

ntervening plains. Sparsely cratered, similar to units Ip and Im. Contains a few rille-like features. Albedo intermediate. Queried where could be units

Principally volcanic constructional features with intervening volcanic flows on

ash fall deposits. Topographic character locally may be inherited from pre-

Imbrian hummocky materials deposited in outer depressed ring of Nectaris

basin, analogous to hummocky materials in outer depressed rings of the freshe

Orientale and Imbrium basins; these may be impact-fractured bedrock or basin

Topographically elevated terrain—ridges, mounds, plateaus, and irregular tracts;

mostly part of concentric rings of the multi-ringed Nectaris basin (shown by

arge dots). Mostly hilly to broadly rolling, uneven on fine scale to fairly smooth

(in west-central part of quadrangle). Albedo intermediate. Includes higher

mountains whose sharp peaks have high albedo, as in more extensive tracts of

Inferred veneer having very low to low albedo in irregular patches on smooth

to hilly mare and upland terrain; little apparent intrinsic topographic relief

Possibly thin layers of volcanic ash and ejecta; may be constructional volcani

deposits at Gaudibert and Gaudibert B. Post-dates Copernican rim material of

craters Theophilus and Mädler near western border of quadrangle; could be pre-

Albedo high to very high; on steep slopes, mainly inner walls of craters; locally

on unit cp and on steep slopes in old regional materials (unit pIt) but not shown.

On gentle southwest-facing slope east of crater Mädler, has grooved and ropy

May also form hill in Gaudibert where appears smeared and streaky, and hilly

ejecta (see text). May locally be younger than Imbrian Materials of impact craters, similar in origin to younger crater units, more degraded. Formation of crater Gutenberg by impact probably breached north all of older crater Gutenberg South (informal name), resulting in deposition (rregular to elongate hillocks, mostly < 1 km across, and narrow (< 1 km) ir of asymmetric lobe of ejecta to south. Floor and peak materials, impact-inuced crater-floor volcanic material or impact-brecciated lenses brought up regular furrows, at places separated by narrow, irregular plains. Similar to units Ih and IpIh but hillocks less equidimensional. Limited to crater floors

where could be units Ih or IpIh

pIt, hilly and rugged terra material, undivided

and Tabor, 1972: Wilhelms, 1972)

terrain in and southeast of Gaudibert B

Cd, dark material

Copernican elsewhere

texture radial to Mädler

Em, dark mare material

Cs, slope material

Csc, Csct, Cscs, Cscl, satellitic crater materials Volcanic constructional terrain; alternatively, veneer of volcanic or regolithic Irregular crater swarms or single craters similar to those in swarms. Individmaterials partly subduing older irregular terrain of uncertain origin. Possibly similar in origin to units Ih and IpIh ual craters mostly asymmetric and shallow with respect to width; rims compar-

tively low but crests fairly sharp; rim crests commonly arcuately irregular in plan view, composed of two or more merging circular to elliptical craters. IpIh, subdued hummocky material Largest crater clusters >10 km in length; individual craters mostly <5 km. Similar to unit Ih but more subdued, and small craters more abundant. Occurs Clusters occur in ropy, commonly en echelon, arcs and loops, commonly associated with ray materials traceable to large Copernican craters outside quadranprincipally in central part of quadrangle. Contains a few rille-like features. Albedo intermediate. Queried where could be units Ii or Ih le; this association indicated as follows: Csct, Tycho (one mapped occurrence 1/2° S., 35 1/2° E.; numerous additional small, <11/2 km, sharp circular, bright craters present in Tycho rays); Cscs, Stevinus group (Stevinus, Stevinus A, or Similarity in topographic form to unit Ih suggests common origin; possibly possibly Furnerius A); Cscl, Langrenus; Csc, mostly part of satellitic field of formed by earlier episode of volcanism, or same material partly covered by Theophilus. Albedo intermediate to locally high. Queried where could be unit pyroclastic material or fragmental regolith. Greater apparent age makes relation to Nectaris basin more likely than for unit Ih

Secondary impact craters excavated by material ejected from large primary impact craters indicated by letters. Irregular craters probably formed by comparatively low-angle impact of ejecta, mostly from nearby Theophilus and Langrenus; circular secondary craters, which have topographic characteristics of small primary craters, probably formed by comparatively high-angle, highenergy impact of material from more distant primary craters (Tycho and

pIcr2, rim material. Albedo intermediate. For largest craters (Gutenberg and

pIfp, irregular floor and peak materials. Low relief, irregular topography in

crater floors; locally near crater center includes low to prominent hills of

rregular shape and distribution. Albedo intermediate; intermediate to high

pIcw2, wall material. Hummocky, terraced. Albedo high to intermediate

MATERIALS OF IRREGULAR AND SUBDUED CRATERS

with Gutenberg material on northwest and southeast

Colombo), broadly to faintly hummocky, similar to unit IpIh which merges

s, material of subdued craters

Ici, material of irregular craters

pIc2, crater material, undivided

on steep slopes of hills

Bowl-shaped craters of low relief; rim crests gently rounded and low; topography generally smooth and subdued but locally hilly; irregular or elliptical and ocally circular in plan; mostly <3 km across. Similar to small Imbrian craters usters occur in unit Ih in Isidorus B and C. Albedo same as surrounding

in relief and to many individual Copernican satellitic craters in plan shape

Mostly volcanic; may include some secondary or primary impact craters

Volcanic or secondary impact craters of basins (see text)

airly sharp-rimmed to locally subdued craters of irregular outline; rims mostly ow and rim materials narrow. Floors commonly occupied by diverse, irregular to smooth, filling materials. Albedo of walls high to intermediate. Some elongated or alined north-westwardly radial to Imbrium basin and generally coincident with regional northwest-trending fracture system. Queried where could be pre-Imbrian

pIc, material of incomplete craters (ring structures) Wall and rim materials of highly subdued, circular, polygonal, irregularly elliptical, or compound craters; walls and rims smooth, low, and comparatively nar-

row. Outlines locally obscured by mantling materials. Albedo intermediate; aguerre, in Mare Nectaris, dark Volcanically modified impact craters and calderas possibly developed on sites of old impact craters. Some rims and walls apparently terminate against scarps

(east of Censorinus N) and possibly predate Nectaris basin. Daguerre buried by mare materials pIci, material of irregular craters Similar to unit Ici but craters more subdued and degraded. In western part of

Queried where could be Imbrian Some may be secondary impact craters of a pre-Imbrian basin (most likely Crisium or Serenitatis). Many may be old calderas HILLY MATERIALS

quadrangle, apparent north-northeast trend; elsewhere, irregularly distributed.

tm, terra mound material

Iilly, rounded, amorphous-appearing, apparently constructional mounds and mantles of irregular outline; surfaces smoothly irregular. Locally obscures crater materials in uplands; lacks structural "grain" of underlying crater rims, nearby regional materials, and regional fracture systems. Some occurrences contain low-rimmed craters (unit cs). Albedo mostly intermediate olcanic extrusive and intrusive materials, perhaps composed of intermediate or silicic differentiated rocks. Positions and morphology of low-rimmed craters suggest related origin

cp, crater peak material opographically distinct, individual and compound peaks in crater floors. Albedo mostly high. In Capella, peak subangular and comparatively large Volcanic constructional features in some craters (for example in Capella); com-

pound peaks in centrally uplifted parts of impact crater floors (for example Colombo) may be breccia lenses modified by volcanism Diverse material occupying and substantially filling Bohnenberger and Gaudibert, and possibly underlying mare material in Daguerre. Albedo intermediate to locally high in steep slopes; low in Daguerre. Forms crackled, extremely ir-

orms hilly, irregular, faulted terrain appearing smooth and smeared in fine detail. Queried in Daguerre where could be other hilly unit

regular, jagged terrain in Bohnenberger; floor upwardly convex, crossed by

gashes and narrow trenches producing a breadcrust-like texture. In Gaudibert,

Ih, hummocky material

Hilly to hummocky. Myriads of fairly distinct, roughly circular to elongate hills, mainly about ½ to 2 km across, in part irregularly separated by plains Principally in crater floors (mainly units Ici, pIci, and pIc) and in broad northtrending valley in northeastern part of uplands where the elongate hills trend north-south; passes abruptly into unit IpIh in southern part of valley. Crater floor occurrences more distinctive and tend to consist of larger hills; locally ≈3 km across in craters Isidorus B and C; crater occurrences commonly lack

. Most craters <3 km are not shown on the map 2. Qualitative reflectance (albedo) terms used here spond to the following approximate numerical values (Pohn and Wildey, 1970): very low, < 0.1 low, 0.10-0.12; intermediate, 0.12-0.14; high, 0.14-0.16; very high, >0.163. Areas in the mare and uplands of the Colombo quadrangle that cool anomalously slowly during eclipse materials of inferred impact craters of Copernican and Eratosthenian age; include high-, intermediate-, and low-albedo crater rim materials

Relative ages of structures and geologic units have been determined from intersection and apparent overlap relations and from morphologic freshness reflecting degree of preservation. The fivefold crater-age sequence is based on the classification of Shoemaker and Hackman (1962) and corresponds broadly to a modified classification of Pohn and Offield 1970) and Offield (1971). Rock units in the quadrangle are provisionally correlated with time-stratigraphic units first described in and near the Imbrium basin (Shoemaker, 1962 a, b; Shoemaker and Hackman, 1962, Shoemaker and others, 1963) and subsequently recognized elsewhere on the near side of the Moon (McCauley, 1967; Wilhelms, 1970; Wilhelms and McCauley, 1971). Some aspects of the geology of this quadrangle are reported elsewhere (Elston, 1964; 1965, 1966 a, 1968, 1971; and Lunar Orbiter Photo Data Screening Group, 1968, p. 54-57; 60-62). A variety of terra and mare materials in and around the northeast part of the ancient multi-ringed Nectaris basin are included in this quadrangle. Diverse features and structures both related to and younger than the Nectaris basin are preserved because the region lies well away

INTRODUCTION

from younger basins (Offield and Pohn, 1970; Stuart-Alexander and Howard, 1970), and escaped masking effects that accompanied their for-Four broad categories of materials are recognized: (1) materials of circular and elliptical craters (mainly impact craters); (2) materials of irregular and subdued craters (volcanic craters and calderas, secondary impact craters, and craters of uncertain origin); (3) hilly materials that form constructional or chaotic terrains (volcanic or basin-related); and (4) fill and veneering materials (mainly volcanic).

GEOLOGIC UNITS

MATERIALS OF CIRCULAR AND ELLIPTICAL CRATERS

Structural and morphologic characteristics of these craters and

and rim crests, and their walls are more commonly hummocky and chan-

neled. Several craters mapped as pre-Imbrian are larger than the largest

young craters that have dark or light-dark streaky rims, and young

ky bright-halo craters such as Censorinus, may indicate fundamental

materials appear mainly attributable to impact. Features include floors that lie far below crater rim crests and the general level of the surrounding terrain; smooth and terraced crater walls; near-circular to elliptical rim crest outlines; hummocky rim materials that grade away from the craters into ropy and braided radial-rim facies; and surrounding rays and swarms of satellitic craters. Rays and fine-scale morphologic features are apparently degraded and lost with increasing age. Craters assigned to the Copernican, Eratosthenian, and Imbrian Systems (units Cc, Ec, and Ic, respectively, and their subdivisions) have a decidedly youthful morphology. The craters and their rim deposits are mostly complete, and crater rim crests are fairly sharp. Copernican craters—the youngest craters—exhibit halos under full-Moon illumination; large craters, such as Theophilus (60 km west of the Colombo quadrangle and about 95 km across), are surrounded by rays containing pronounced arcuate chains of satellitic or secondary impact craters (unit Csc). Eratosthenian craters are morphologically similar to Copernican craters, but they are somewhat degraded and they lack distinct bright or dark halos in their rim deposits. Imbrian craters display smooth, intermediate-albedo rim materials; crater walls are mostly smooth and short; the floors contain various filling materials that include crackled and bulbous constructional material, hilly materials, and fairly smooth plains material; rim crests are subpolygonal to nearly circular, fairly sharply defined, and largely complete. The identifiable rim deposits are somewhat narrower and the rim crests more subdued than in Copernican and Eratosthenian craters of comparable size. Imbrian craters predate emplacement of mare material (unit Im) that forms most of the present mare surface. Pre-Imbrian craters form that part of the crater population which appears decidedly old. They formed between the times of formation of the Nectaris and Imbrium basins. Two general ages (unit pIc, and pIc, and their subunits), which broadly correspond to craters middle and late pre-Imbrian age mapped elsewhere on the Moon (Offield, 1971), are recognized. In contrast to the Imbrian craters, pre-Imbrian craters commonly display topographically more irregular rim materials

The elliptical pair of Copernican craters Messier and Messier A, in the northeast, is inferred to have formed by a low-angle double impact from the east (of a body which may have fissioned shortly before impact) or the basis of asymmetric crater shapes and ejecta patterns (Elston, 1967, 968, 1971). Their elliptical shapes indicate an impact angle of perhaps 15° or less from horizontal judging from experimental hypervelocity impact studies by Gault, Quaide, and Oberbeck (1966; 1968, p. 95-96 and fig. 14). A larger and older elliptical oblique impact crater may be represented by Goclenius (pre-Imbrian), which measures 50 by 75 km. Dark, smooth parts of the rim deposits of the Messier pair may indicate that dark volatile-rich materials were introduced into the ejecta by the impacting body (Elston, 1971). Similar dark smooth halos occur at other presumed impact craters, notably Bellot, whose rim is dark where on mare and brighter where on uplands. The contrast between these

There is an apparently anomalous overlap relation between the craters rus and Capella. Isidorus appears less degraded, therefore younger than, Capella, but seems to be overlapped by the Capella rim. This apparent paradox may result from (1) deposition of younger volcanic rock unit tm) which gives the illusion of being part of the Capella rim; (2 Isidorus having formed too far away to have breached the topographically higher Capella rim; or (3) a volcanic origin of Capella giving it a softer initial appearance (Offield and Pohn, 1970, p. C167).

ences in composition of the impacting body.

MATERIALS OF IRREGULAR AND SUBDUED CRATERS These craters have diverse form and origin. Most satellitic craters (unit Csc) of large Copernican craters are irregular in plan and crosssection, and are believed to be of secondary impact origin (Shoemaker, 1962a). (In addition, a number of small, circular, bright-halo crater nmapped) in and near Mare Nectaris occur in ray material of the large distant, rayed crater Tycho and are therefore inferred to be the products of high-angle, high-energy secondary impacts; small, near-circular, brighthalo craters thus should not be assumed to be primary impact craters until possible associations with distant craters have been evaluated.) Subdued craters (unit cs) are comparatively small, low-rimmed, com monly irregular to near-circular craters that may be volcanic in origin although many resemble degraded satellitic craters or older circular craters and could be pre-Copernican secondary or primary impact craters. Many occur in clusters in hummocky and hilly crater filling materials. Bowl-shaped subdued craters have formed within two somewhat larger inferred impact craters (Censorinus F, Eratosthenian; and Crozier H Imbrian), making a crater-in-crater structure of possible mixed origin. Imbrian and pre-Imbrian craters of irregular outline (units Ici and pIci djacent quadrangles distinguished as rugged terra material (Stuart-Alexander form a distinctive part of the crater population. They are too irregular to be primary impact craters and too large to be secondary impact craters

Pre-basin materials uplifted during formation of Nectaris basin and covered by of other craters. The younger ones (unit Ici) may be secondary impact craters of the Imbrium basin, as they are similar in general form, size, basin ejecta; ejecta thinnest on rugged terrain because of shedding, and prebasin rock may be exposed. Probably additionally covered by post-basin volorientation of the group, and distance from the basin to other craters that are so interpreted (Wilhelms and McCauley, 1971). However, they canic and impact materials, possibly including ejecta of younger basins are somewhat sharper topographically than the most likely Imbriun secondary craters and are less closely clustered. They could be of vol FILL AND VENEERING MATERIALS canic origin. Their dominant grouping in a northwest-trending belt, generally radial to the Imbrium basin, also corresponds to the major

> irregular craters (unit pIci) appear to trend north-northeast—a direction that is subradial to the Crisium and Serenitatis basins to the north but which also generally corresponds to the trend of the regional north-south fracture system. Thus, the irregular craters may be of either an initial impact or an initial volcanic origin. If any craters secondary to the Serenitatis and Crisium basins exist in the quadrangle, they are probably in the population of pre-Imbrian irregular craters. Subdued ring structures (unit pIc) of uncertain origin appear to in clude the oldest crater-form structures in the quadrangle. Although some may be modified pre-Imbrian impact craters, materials in and around the ring structures appear to be much younger and to be domin antly volcanic. Some ring structures in the northern part of the quadrangle may be relicts of craters that existed before formation of the Nectaris basin, but the relatively undeformed character of the large mare-mantled ring structure Daguerre in Mare Nectaris suggests that

northwest-trending fracture system of the region. Several of the older

most ring structures, although old, post-date formation of the Nectaris

Old rugged and hilly mountains, mapped as unit pIt, probably repre-

FILL AND VENEERING MATERIALS

These include volcanic(?) filling materials that form plains whose

albedo is intermediate (unit Ip), low (unit Im), and very low (unit Em),

and veneering and smoothing materials of uncertain origin. The plains

units at places contain narrow, straight-walled and sinuous rilles, and

associated low-rimmed, maar-like craters that occur singly and in chains.

the mare-terra contact. Some mare material near Daguerre is strongly

Park, comparatively young mare material (Em) occurs principally near

Most material mapped as dark veneering material (unit Cd) has no

apparent intrinsic topographic relief and its irregular distribution does

not obviously conform to topographic and morphologic features. There

are no apparent source features in the Colombo quadrangle, or in the

Theophilus quadrangle to the west (Milton, 1968), for the dark veneering

material that overlies part of the ring structure Daguerre and part of

the Copernican crater Mädler. Dark material in Gaudibert, however,

appears associated with a presumed volcanic hill, and dark material in

and southwest of Gaudibert B appears associated with a hilly, cratered,

STRUCTURE

NECTARIS AND FECUNDITATIS BASINS

All main rings of the multi-ringed Nectaris basin (Hartmann and

Kuiper, 1962) are present in the quadrangle. The inner part of the basin

is occupied by Mare Nectaris. This mare contains a central deep in

tures. The most conspicuous feature is a north-south trending, "mid-

sea" ridge which bisects the basin deep. The deep is surrounded by a

bench in which mare material displays a number of discontinuous ridges

concentric with the deep and topography that appears to reflect under-

southwest, the Altai Scarp (Rowan, 1971) outlines the margin of the

Nectaris basin, and interior from it are other inward-facing concentric

scarps (Hartmann, 1964, fig. 1). In uplands of the Colombo quadrangle

less well developed but probably equivalent scarps occur in the Censor

is similar to the Imbrium and Crisium basins in that concentric ring

structures appear best developed on one side of the basin (see Hartmann,

1964, fig. 1), but contrasts with the Orientale basin, which is surrounded

by apparently more complete concentric scarps that produce a bulls-eye

effect (see Lunar Orbiter IV, medium-resolution photographs 187, 193

194). The major multi-ringed basins display features which suggest tha

they are the products of giant impacts (for example, see Gilbert, 1893

Baldwin, 1949, 1963; Shoemaker, 1962a; Urey, 1962), and the development

of complete and incomplete concentric scarps may be related to the

tween the Nectaris and Crisium basins. The lowland area may partly ow

its existence to depressions caused by formation of these two circular

basins, and it also appears to have been the site of one or more old larg

craters. Subdued, east-facing scarps west and south of the Messier

ther to the west, northwest-trending grabens and fractures, in mare and

upland, curve northward to outline the depression. East of the quad-

rangle, an arcuate mare ridge, concave to the west, more regularly out-

lines the east side of a crater-form depression, the diameter of which is

about 200 km. Gravity data derived from perturbations of orbiting

beneath Mare Fecunditatis (Muller and Sjogren, 1968) — a feature shared

by Nectaris and most other, although not all (Gottlieb and others, 1969), major lunar circular basins. The Fecunditatis depression thus appears

to be localized around one or more subdued, subbasin-sized craters.

spacecraft have failed to reveal a positive gravity anomaly, or mascon

craters irregularly outline the western part of a broad depression. Fa

Mare Fecunditatis occupies a broad lowland area about midway be-

angle and direction of penetration of the impacting body.

inus plateau (informal name) and Montes Pyrenaei. The Nectaris basin

sent remnants of incomplete mountain rings of the Nectaris basin cov-

ered by a variety of deposits, including ejecta of the Nectaris basin.

HILLY MATERIALS Freshly, exposed, shock-whitened brecciated rock (Elston and Holt, 1967), prob-Occupying some craters are volcanic(?) deposits (unit cf) that are ably both bedrock and talus uncovered during continuing downslope movement. Material near Mädler probably produced by impact and deposition of Mädler bulbous to hilly and locally crackled. Crackled material occurs in the smooth-rimmed crater Bohenberger, and strongly hilly material occurs in the ring structure Gaudibert. Although the deposits may be volcanic, some of the craters may be of impact origin. The extensive regional hummocky units Ih and IpIh occur mostly in depressed belts that in part are roughly concentric with Mare Fecundi Smooth plains; occurs principally near mare margins. Albedo very low to low

and rille-bearing terrain.

tatis and Mare Nectaris. They are similar in morphology and position lower than Imbrian mare. Contacts with Imbrian mare drawn on basis of alrelative to the basins, to materials surrounding the fresher Orientale and bedo differences; mostly not reflected by topography or crater density. Locally Imbrium basins which have been interpreted as impact-fractured bedcontains sinuous rilles. May also occur in and near Gutenberg and Gutenberg rock or basin ejecta (Page, 1970; Scott, 1972; M'Gonigle and Schleicher E and near Goclenius 1972). However, the units in the troughs of the Colombo quadrangle especially the relatively young-appearing unit Ih, occur within, and ap-Volcanic materials, mainly flows with subordinate pyroclastics. Albedo may pear to overlap, a variety of craters that are younger than the Nectaris reflect composition not age, and much could be Imbrian; some may be Coperbasin. Because of this, units Ih and IpIh are considered to be principally of volcanic rather than direct impact origin.

Im, Imd, mare materials Im, mare material. Fairly smooth, level to gently undulating plains material of low albedo; forms most of the maria. Near margin of Mare Nectaris, locally forms irregular to rough dark surfaces that may reflect subjacent topography; at places in Mare Fecunditatis, forms broad, low plateaus. Locally contains sinuous rilles

Imd, material of smooth dome-like features in maria Im, volcanic materials, mainly flows, possibly with associated pyroclastics; probably much like basaltic rocks returned from nearby Tranquillity Bas Lunar Sample Prelim. Exam. Team, 1969). Approximately correlated wit mbrian mare material of Mare Imbrium and Oceanus Procellarum on basis f morphology, albedo, and crater density

Imd, extrusive volcanic domes, laccoliths, or shield volcanoes Ip, plains material Surface mostly level and fairly smooth. Albedo intermediate. General morphology mare-like: crater population similar to or somewhat greater than that

of unit Im. Occupies floors of some older craters, and mantles parts of uplands; forms plateaus in northern highlands, and plains in central and south-centra parts of quadrangle, where locally appears to be overlapped by mare material Volcanic flows and subordinate pyroclastics. Underlies mare material in crate Fracastorius in southern part of Mare Nectaris (Elston, 1966b), so may constitute major basin filling unit beneath mare material

Uneven, but broadly level surfaces; more irregular and uneven in detail than unit Ip; conforms to and apparently subdues pre-existing relief of more rugged

Veneering and smoothing materials of diverse origin, possibly partly or largely volcanic; probably includes mass-wasted fragmental debris locally derived from adjacent slopes and moved by combination of gravity and impact-induced seis mic transport. Possibly also includes fine debris derived from distant post-Nectaris basin-forming and cratering events

Concealed crater rim crest

Rim crest of dark halo crater

Discontinuous mountain rings of Nectaris basin

(Saari, Shorthill, and Fulmer, 1966), coincide with

LUNAR GRID SYSTEM The reticulate lunar grid system (Puiseaux, 1907; Baldwin, 1963, chap. c; Strom, 1964) is a cross-hatched pattern of northwest-, northeast-, and orth-trending fractures, best developed in the uplands; they may have nalogs in regional fracture and lineament systems on Earth (Puiseaux 1907; Vening Meinesz, 1947; Boutakoff, 1952). The Moon-wide distrib tion and symmetry of the lunar grid system suggests it is a primary fracture system formed during cooling and solidification. In the Colombo quadrangle, later structural adjustments have taken place within it. Some of the grabens of the conspicuous northwest-trending fracture system cut mare as well as terra material. Parallel and subparallel, en echelon grabens range, individually, from about 50 to 250 km in length. The most strongly developed zone of grabens extends, with short disentinuities, northwestward from Goclenius toward the Imbrium basin, nto sculptured terrain which Gilbert (1893) noted to radiate from the mbrium basin and which he attributed to effects accompanying the impact formation of the basin. At least some of the graben faulting in the Colombo quadrangle, however, post-dates formation of Imbrian and younger mare materials and cannot have occurred as a direct conse quence of the impact formation of the Imbrium basin. Because there is o evidence to link the more recent graben faulting with Imbrian and younger cratering events, the comparatively recent faulting would appear to have occurred in response to internal structural adjustmentsadjustments that followed, and that perhaps were related to, outpourings of mare material.

GAUDIBERT VOLCANIC ZONE Many volcanic features occur near the northeast margin of Mare Nectaris in a northwest-trending zone centered on the crater Gaudibert. robable constructional deposits (unit Ii) occur in the zone; young, dark volcanic(?) material (unit Cd) and associated craters and rilles occur in and southeast of Gaudibert; crackled and hilly deposits (unit cf) f Bohnenberger and Gaudibert; and probable volcanic deposits (units Ih and tm) occur near and in Capella and Isidorus. This volcanic zone may be localized where the structurally disturbed margin of the Nectaris basin and northwest-trending fractures of the lunar grid system intersect

STRUCTURES IN MARE MATERIALS Structures and structurally associated features in the maria include: (1) diverse volcanic(?) features; (2) mare ridges; and (3) faults and The probable volcanic features include sinuous and narrow linear rilles. locally having associated chain craters and isolated subdued, possibly maar-type craters; pit craters and small apparent calderas; cratered cones; domes; and scarps (in Mare Fecunditatis) that mark possible flow ronts and the margins of low lava plateaus. Sinuous rilles commonly ave a low-rimmed crater at their head ends, which suggests that at east some rilles are of volcanic flow origin. Narrow linear rilles probably are developed along and reflect underlying fractures or fissures. few pit craters occur in Daguerre, in and near Gaudibert B, and east of Lubbock H. Low, convex-upward domes that lack summit craters are irregularly distributed across the maria and are inferred to be volcanic piles or intrusive bodies. Mare ridges mark places of possible upwelling of mare material. On the Nectaris bench their trends appear concentric with the basin marn, whereas two north-trending ridges cross-cut the Nectaris basin deep. mare Fecunditatis linear ridges east of Lubbock occur in a broad lateau-like area that may be of constructional volcanic origin. Mare ridges in Mare Fecunditatis also outline and interconnect several mantled pre-mare crater-form features. Daguerre in Mare Nectaris is a similar crater-form feature outlined by mare ridges.

COPERNICAN UPLAND FAULTING Copernican faulting in the uplands has occurred where an arcuate normal fault, nearly 40 km long, intersects the west rim and wall of the crater Capella A (Copernican). The arc is broadly concave westward and the trace of the southern part of the fault is braided in fine detail. splacement is down on the west.

GEOLOGIC HISTORY The earliest recognizable event in the Colombo quadrangle is the formation of the Nectaris basin, probably by impact, which resulted in deposition of regional material around the basin and formation of disontinuous, concentric, upland rings. Random impact cratering has since egraded the topographic character of the basin. Some of the craters rmed during pre-Imbrian time are irregular craters which formed either by volcanism or by secondary impacts from the Serenitatis or Crisium basins. Regional units of hummocky terrain and rolling plains also were deposited in the terra. Impact formation of the Imbrium basin, 1,000 km to the northwest, may have reactivated grid-system faults along the northwest-trending racture system and may also have produced secondary impact craters in The Imbrian Period was marked by extensive regional and local volcanic activity of diverse types. Volcanic activity apparently occurred locally to fill or modify some inferred impact craters. Plains material of intermediate albedo flooded low upland areas and the floors of craters naterial. Imbrian mare material then flooded the lowlands. Mare material and possibly some of the various hummocky and smooth, antling and filling materials of inferred volcanic origin continued to sporadically through Eratosthenian and possibly into Copernican time. Post-Imbrian faulting has occurred on the northwest-trending graben system, and may reflect deep-seated structural adjustments fo

haloed craters, possibly differing in albedo because of differing bolide compositions, were among the most recent features formed; many craters without such halos probably had halos when first formed. REFERENCES Baldwin, R. B., 1949, The face of the Moon: Chicago, Chicago Univ. Press, __1963, The measure of the Moon: Chicago, Chicago Univ. Press, Boutakoff, N., 1952, The great circle stress pattern of the Earth: Australian Jour. Sci., v. 14, p. 108-111. Elston, D. P., 1964, Pre-Imbrian stratigraphy of the Colombo quadrangl in Astrogeologic Studies Ann. Prog. Rept., Aug. 25, 1962 to July 1, 1963, pt. A: U.S. Geol. Survey open-file report, p. 99-109. _1965, Stratigraphic relationships of the eastern part of the Moon [abs.]: Geol. Soc. America Spec. Paper 82, p. 56. __1966a, Preliminary geologic map of the Colombo quadrangle of July 1, 1965: U.S. Geol. Survey open-file report. July 1, 1965: U.S. Geol. Survey open-file report.

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